Genes and Cells 2018 vol.13 N2, pages 39-46

The effect of oxygen concentration on embryo development and assisted reproductive technologies efficiency

Zhiryaeva E., Kiassov A., Rizvanov A.
Kazan Federal University, 420008, Kremlevskaya 18, Kazan, Russia

Abstract

© 2018 Human Stem Cell Institute. All rights reserved. Many different factors have an effect on the preimplantation development of embryos under conditions in vitro. One of these factors is the oxygen concentration in the culture medium. Currently, IVF labs have ability to cultivate embryos either under conditions of atmospheric oxygen concentration or at low oxygen concentration (hypoxia). This review is focused on the analysis of up to date research and clinical results which are trying to establish an "optimal" composition of the gas mixture in the incubator to generate more viable embryos and increase the effectiveness of assisted reproductive technologies programs.

http://dx.doi.org/10.23868/201808018

Keywords

Assisted reproductive technologies, Blastocyst, Cultivation, Environment, Hypoxia, IVF, Oxygen concentration, Preimplantation development

References

[1] Assisted reproductive technology in Europe, 2012: results generated from European registers by ESHRE. Human Reproduction 2016: 31(8): 1638-52.

[2] Leite R.F., Annes K., Ispada J. et al. Oxidative stress alters the profile of transcription factors related to early development on in vitro produced embryos. Oxid. Med. Cell. Longev. 2017; 2017: 1502489.

[3] Guerin P., Mouatassim S., Menezo Y. Oxidative stress and protection against reactive oxygen species in the pre-implantation embryo and its surroundings. Human Reproduction Update 2001; 7: 175-89.

[4] Gupta S., Sekhon L, Agarwal A. The role of oxidative stress and antioxidants in assisted reproduction. Current Women's Health Reviews 2010; 6: 227-38.

[5] Martin-Romero F.J., Miguel-Lasobras E.M., Dominguez-Arroyo J.A. et al. Contribution of culture media to oxidative stress and its effect on human oocytes. Reproductive BioMedicine Online 2008; 17: 652-61.

[6] Fujitani Y., Kasai K., Ohtani S. et al. Effect of oxygen concentration and free radicals on in vitro development of in vitro-produced bovine embryos. Journal of Animal Science 1997; 75: 483-9.

[7] Karja N.W., Wongsrikeao P., Murakami M. et al. Effects of oxygen tension on the development and quality of porcine in vitro fertilized embryos. Theriogenology. 2004; 62: 1585-95. 10.1016/j.theriogenology.2004.03.012.

[8] Agarwal A., Said T.M., Bedaiwy M.A. et al. Oxidative stress in an assisted reproductive techniques setting. Fertility and Sterility 2006; 86: 503-12.

[9] Burroughs CA., Williamson G.L., Golding M.C et al. Oxidative stress induced changes in epigenetic modifying gene mRNA in pre-implantation in vitro bovine embryos. Reproduction, Fertility and Development 2012; 25: 149.

[10] Thannickal V.J., Fanburg B.L. Reactive oxygen species in cell signaling. Am. J. Physiol. Lung Cell. Mol. Physiol. 2000; 279(6): 1005-28.

[11] Johnson M.H., Nasr-Esfahani M.H. Radical solutions and cultural problems: could free radicals be responsible for the impaired development of preimplantation mammalian embryos in vitro? Bioessays 1994; 16: 31-8.

[12] Abe H., Semba H., Takeda N. The roles of hypoxia signaling in the pathogenesis of cardiovascular diseases. J. Atheroscler. Thromb. 2017; 24(9): 884-94.

[13] Hu C.J., Wang L.Y., Chodosh L.A. et al. Differential roles of Hypoxia-Inducible Factor 1 α (HIF-1 α) and HIF-2α in hypoxic gene regulation. Mol. Cell. Biol. 2003; 23: 9361-74.

[14] Thomson J., Itskovitz-Eldor J., Shapiro S. et al. Embryonic stem cell lines derived from human blastocysts. Science 1998; 282(5391): 1145-7.

[15] Ezashi T., Das P., Roberts R. Low O tensions and the prevention of differentiation of hES cells. PNAS USA 2005; 102(13): 4783-8.

[16] Ying Q.L., Wray J., Nichols J. et al. The ground state of embryonic stem cell self-renewal. Nature 2008; 453: 519-23.

[17] Yoshida Y., Takahashi K., Okita K. et al. Hypoxia enhances the generation of induced pluripotent stem cells. Cell Stem Cell 2009; 5: 237-41.

[18] Ramirez M.A., Pericuesta E., Yanez-Mo M. et al. Effect of long-term culture of mouse embryonic stem cells under low oxygen concentration as well as on glycosaminoglycan hyaluronan on cell proliferation and differentiation. Cell Prolif. 2011; 44(1): 75-85.

[19] Lee W.H., Chen W., Shao N.Y. et al. Comparison of Non-Coding RNAs in Exosomes and Functional Efficacy of Human Embryonic Stem Cell-versus Induced Pluripotent Stem Cell-Derived Cardiomyocytes. Stem Cells 2017; 35(10): 2138-49.

[20] Shin J.M., Kim J., Kim H.E. et al. Enhancement of differentiation efficiency of hESCs into vascular lineage cells in hypoxia via a paracrine mechanism. Stem Cell Research 2011; 7: 173-85.

[21] Tsang K.M., Hyun J.S., Cheng K.T. et al. Embryonic Stem Cell Differentiation to Functional Arterial Endothelial Cells through Sequential Activation of ETV2 and NOTCH1 Signaling by HIF1. Stem Cell Reports 2017; 9(3): 796-806.

[22] Fischer B., Bavister B. Oxygen tension in the oviduct and uterus of rhesus monkeys, hamsters and rabbits. J. Reprod. Fertil. 1993; 99: 673-9.

[23] Kovacic B. Culture systems: low-oxygen culture. Methods Molecular Biology 2012; 912: 249-72.

[24] Dumoulin J.C., Meijers C.J., Bras M. et al. Effect of oxygen concentration on human in-vitro fertilization and embryo culture. Human Reproduction 1999; 14: 465-9.

[25] Bahceci M., Ciray H., Karagenc L. et al. Effect of oxygen concentration during the incubation of embryos of women undergoing ICSI and embryo transfer: a prospective randomized study. Reproductive Biomedicine Online 2005; 11: 438-43.

[26] Petersen A., Mikkelsen A.L., Lindenberg S. The impact of oxygen tension on developmental competence of post-thaw human embryos. Acta Obstetricia Et Gynecologica Scand. 2005; 84: 1181-4.

[27] Rinaudo P., Giritharan G., Talbi S. et al. Effects of oxygen tension on gene expression in preimplantation mouse embryos. Fertility and Sterility 2006; 86 Suppl 3: 1252-65.

[28] Kea B., Gebhardt J., Watt J. et al. Effect of reduced oxygen concentrations on the outcome of in vitro fertilization. Fertility and Sterility 2007; 87: 213-6.

[29] Cieslak Janzen J.M., Graff D., Anderson S. et al. Comparison of atmospheric oxygen versus low oxygen on human sibling embryo development. Fertil. Steril. 2008; 90: 431.

[30] Kovacic B., Vlaisavljevic V. Influence of atmospheric versus reduced oxygen concentration on development of human blastocysts in vitro: a prospective study on sibling oocytes. Reproductive Biomedicine Online 2008; 17: 229-36.

[31] Waldenstrom U., Engstrom A., Hellberg D. et al. Low-oxygen compared with high-oxygen atmosphere in blastocyst culture, a prospective randomized study. Fertility and Sterility 2009; 91: 2461-5.

[32] Ciray H., Aksoy T., Yaramanci K. et al. In vitro culture under physiologic oxygen concentration improves blastocyst yield and quality: a prospective randomized survey on sibling oocytes. Fertility and Sterility 2009; 91: 1459-61.

[33] Meintjes M., Chantilis S., Douglas J. et al. A controlled randomized trial evaluating the effect of lowered incubator oxygen tension on live births in a predominantly blastocyst transfer program. Human Reproduction 2009; 24: 300-7.

[34] Graham J., Richter K., Siques J. et al. Improved preimplantation development and higher pregnancy rates associated with 6% versus ambient oxygen concentration during in vitro embryo culture. Hum. Reprod. 2010; 25: i59.

[35] Kovacic B., Sajko M., Vlaisavljevic V. A prospective, randomized trial on the effect of atmospheric versus reduced oxygen concentration on the outcome of intracytoplasmic sperm injection cycles. Fertility and Sterility 2010; 94: 511-9.

[36] Mitsoli A., Kolibianakis E.M., Loutradi K. et al. Low oxygen embryo culture is associated with improved day 3 embryo quality: a prospective randomized controlled trial. Hum. Reprod. 2011; 26: i2.

[37] Sobrinho D.G., Oliveira J.B., Petersen C.G. et al. IVF/ICSI outcomes after culture of human embryos at low oxygen tension: a meta-analysis. Reproductive Biology and Endocrinology 2011; 9: 143-54.

[38] Bontekoe S., Mantikou E., van Wely M. et al. Low oxygen concentrations for embryo culture in assisted reproductive technologies. Cochrane Database of Systematic Reviews 2012; 7. doi:10.1002/14651858.CD008950.pub2.

[39] Wale P., Gardner D. Oxygen regulates amino acid turnover and carbohydrate uptake during the preimplantation period of mouse embryo development. Biology of Reproduction 2012; 87(1): 1-8

[40] Houghton F., Hawkhead J., Humpherson P. et al. Non-invasive amino acid turnover predicts human embryo developmental capacity. Human Reproduction 2002; 17: 999-1005.

[41] Gardner D., Wale P., Collins R. et al. Glucose consumption of single post-compaction human embryos is predictive of embryo sex and live birth outcome. Human Reproduction 2011; 26: 1981-6.

[42] Harlow G.M., Quinn P. Foetal and placenta growth in the mouse after preimplantation development in vitro under oxygen concentrations of 5 and 20%. Australian journal of biological sciences 1979; 32: 363-9.

[43] Kasterstein E., Strassburger D., Komarovsky D. et al. The effect of two distinct levels of oxygen concentration on embryo development in a sibling oocyte study. Journal of Assisted Reproduction and Genetics 2013; 30: 1073-9.

[44] Mantikou E., Bontekoe S., Wely V. et al. Low oxygen concentrations for embryo culture in assisted reproductive technologies. Human Reproduction Update 2013; 19(3): 209.

[45] Paternot G., Debrock S., D'Hooghe T.M. et al. Can embryo quality be improved by in vitro exposure to low oxygen concentration or by using a miniincubator? Two randomized controlled trials. Fertil. Steril. 2013; 100: 247-8.

[46] Guo N., Li Y., Ai J. et al. Two different concentrations of oxygen for culturing precompaction stage embryos on human embryo development competence: a prospective randomized sibling-oocyte study. International Journal of Clinical and Experimental Pathology 2014; 7(9): 6191-8.

[47] Peng Z., Shi S., Jin H. et al. Impact of oxygen concentrations on fertilization, cleavage, implantation, and pregnancy rates of in vitro generated human embryos. International Journal of Clinical and Experimental Medicine 2015; 8(4): 6179-85.

[48] Nastri C.O., Nobrega B.N., Teixeira D.M. et al. Low versus atmospheric oxygen tension for embryo culture in assisted reproduction: a systematic review and meta-analysis. Fertil. Steril. 2016; 106(1): 95-104.

[49] Yang Y., Xu Y., Ding C. et al. Comparison of 2, 5, and 20% O2 on the development of post-thaw human embryos. J. Assist. Reprod. Genet. 2016; 33: 919-27.

[50] Ali I., Shah S.Z., Jin Y. et al. Reactive oxygen species-mediated unfolded protein response pathways in preimplantation embryos. Journal of Veterinary Science 2017: 18(1): 1-9.

[51] Garcia-Martinez S., Sanchez-Hurtado M.A., Gutierrez H. et al. Mimicking physiological O2 tension in the female reproductive tract improves Assisted Reproduction outcomes in pig. Mol. Hum. Reprod. 2018. doi:10.1093/molehr/gay008.

[52] Piko L., Taylor K. Amounts of mitochondrial DNA and abundance of some mitochondrial gene transcripts in early mouse embryos. Developmental Biology 1987; 123: 354-74.

[53] Galan A., Montaner D., Poo M.E. et al. Functional genomics of 5-to 8-cell stage human embryos by blastomere single-cell cDNA analysis. PLoS One 2010; 5: e13615.

[54] Ma Y.Y., Chen H.W., Chii-Ruey Tzeng C.R. Low oxygen tension increases mitochondrial membrane potential and enhances expression of antioxidant genes and implantation protein of mouse blastocyst cultured in vitro. J. Ovarian Res. 2017; 10: 47.

[55] Greijer A.E., van der Groep P., Kemming D. et al. Up-regulation of gene expression by hypoxia is mediated predominantly by hypoxia-inducible factor 1 (HIF-1). J. Pathol. 2005; 206(3): 291-304.

[56] Maxwell P.H., Pugh C.W., Ratcliffe P.J. The pVHL-hIF-1 system. A key mediator of oxygen homeostasis. Adv. Exp. Med. Biol. 2001; 502: 365-76.

[57] Fujiwara M., Takahashi K., Izuno M. et al. Effect of micro-environment maintenance on embryo culture after in-vitro fertilization: comparison of top-load mini incubator and conventional front-load incubator. J. Assist. Reprod. Genet. 2007; 24(1): 5-9.